Sensing and Spectrum Pooling Techniques for Cognitive Radio Systems

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1. Blind Sensing Techniques for Cognitive Radio Systems:

There are several spectrum sensing techniques that were proposed for CR. A few completely blind sensing methods that does not consider any prior knowledge about the transmitted signal have been derived in the literature, but all of them suffer from the noise uncertainty and fading channels variations. One of the most popular is the energy detector (ED) [U67]. Despite its easy implementation and low complexity, the ED does not perform in low signal-to-noise-ratio (SNR) and cannot differentiate between noise and signals. Moreover, this kind of detector is inconvenient when the level of noise is completely unknown. Four others blind techniques were proposed at EURECOM. The first technique is based on entropy and eigenvalues analysis detector (EAD) [HHDF07]. It investigates the signal subspace to decide whether the primary signal is present or not. The second technique analyzes the distribution of the primary user received signal to sense vacant frequency sub-bands over the spectrum band. Specifically, the distribution analysis detector (DAD) exploits model selection tools through distribution comparison to detect vacant holes in the spectrum band [ZHN08]. For that, we assume that the noise of the radio spectrum band can still be adequately modeled using Gaussian distribution. We then compute and analyze Akaike weights in order to decide if the distribution of the received signal fits the noise distribution or not. Another detector called algebraic detector (AD) exploits the change point detection [GTHZ09]. Indeed, the detection of a used subband corresponds to the presence of "spike-like" in the signal's spectrum which is represented with an *N* order local piecewise model.

For performance evaluation we have chosen to thoroughly investigate the DVB-T primary user system using simulation framework developed with the European research project SENDORA (SEnsor Network for Dynamic and cOgnitive Radio Access). Part of the experimental results obtained during this project is shown on Figure 1.

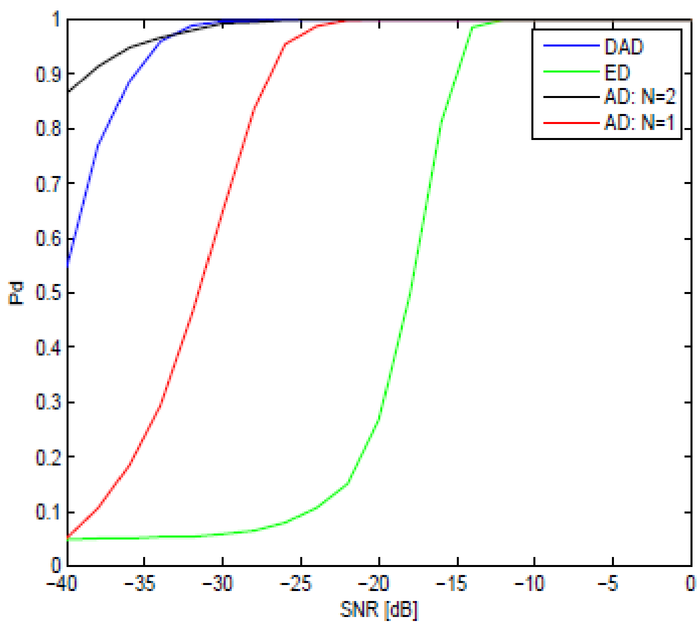

Figure: 1, Probability of detection vs. SNR for the three detectors: energy detector (ED), distribution analysis detector (DAD) and algebraic detector (AD) with *PF* = 0*:*05.

Some of these blind algorithms were also implemented in real time environment in the context of Sendora project [GZH09].

Blind cooperative sensing algorithm based on (EAD) approach was proposed in [ZH09].

2. Centralized and distributed spectrum pooling techniques:

The scheme proposed for the implementation is described in [ZHHO08] where two binary power allocation techniques for cognitive radio networks with centralized and distributed user selection strategies were proposed to operate simultaneously with the primary system without causing harmful degradation. At the core lies the idea of combining multi-user diversity gains with spectral sharing techniques and consequently maximizing the secondary user sum rate while maintaining a guaranteed quality of service (QoS) to the primary system. The target scenarios consider a cognitive radio network consisting of multiple secondary transmitters and receivers communicating simultaneously in the presence of the primary system for both uplink and downlink as depicted in Figure 1. In [ZHHO08], we derived also the maximum number of secondary users that can use simultaneously the spectrum of the primary system for a given network topology and outage probability. The results related to this asymptotic bound can be extended to the context of femto cells and provide the number of maximum femto cells allowed to co-exist with primary system macro cell.

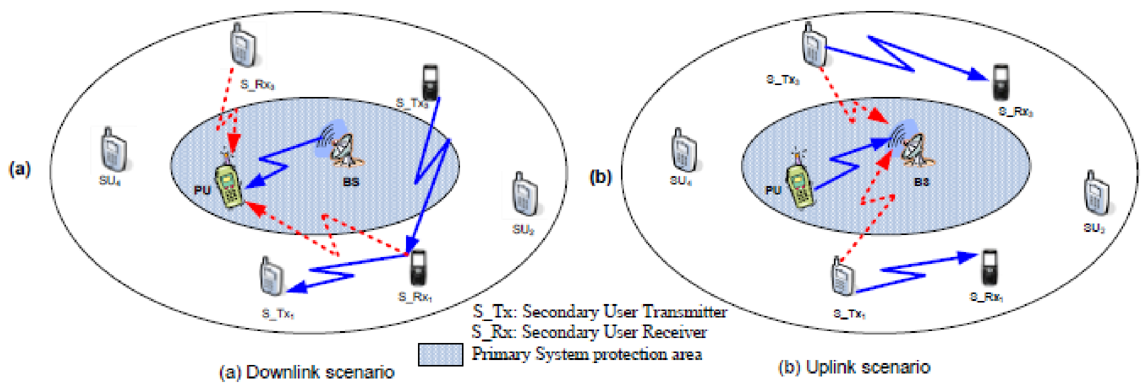

Figure 1 : Cognitive Radio Network with one primary user (PU) and M secondary users (SU)

Centralized Resource Allocation Techniques

In a first step, we present a centralized resource allocation technique. Specifically, we propose to combine cognitive radio with multi-user diversity technology to achieve strategic spectrum sharing and self-organizing communications. From implementation point of view, the centralized scheme will be implemented at the base station side (BTS). Indeed, after receiving the confirmation from the fusion center (FC) about the free holes, the BTS will run the centralized scheme and activate the users that will contribute to fulfill secondary system capacity optimization requirements. The potential benefit from this technique resides in its ability to allow secondary system to operate in both white and gray spectrum holes and to handle the transition between the state where the hole is free and the state where it gets occupied by the primary system. Indeed, thanks to the outage probability approach, the resource allocation strategy will turn off the secondary users that will cause too much interference to the primary system and keep only the ones that guarantee the outage probability constraint (Poutage=1% in our case). This approach prevents from switching off all the secondary users when the sensing block detects primary user activity.

In this centralized mode, the proposed system would require information from a third party (i.e. central database maintained by regulator or another authorized entity) to schedule secondary users coming. In a realistic network, centralized system coordination is hard to implement, especially in fast fading environments and in particular if there is no fixed infrastructure for secondary users, i.e., no back-haul network over which overhead can be transmitted between users. In fact, centralized channel state information for a dense network involves immense signaling overhead and will not allow the extraction of diversity gains in fast-fading channel components. To alleviate this problem, we propose a distributed method where secondary users can get rid of primary user knowledge.

Distributed Resource Allocation Techniques

In the centralized case, the need may exist, as mentioned above, for the perfect knowledge of all channel and interference state conditions for all nodes in the network. To circumvent this problem, the design of so-called distributed resource allocation techniques is crucial. Distributed optimization refers to the ability for each user to manage its local resources (e.g. rate and power control, user scheduling) based only on locally observable channel conditions such as the channel gain between the access point and a chosen user, and possibly locally measured noise and interference. A key example of multi-user resource allocation is that of power control, which serves as a mean for both battery savings at the mobile, and interference management. Here, we focus on binary power control, since it has the advantage of leading towards simpler or even distributed power control algorithms. The approach in the distributed mode consists, as for the centralized mode, in two joint optimization schemes. The first one relates to secondary system capacity maximization and the second optimization takes into account primary system outage probability. From implementation point of view, the resource allocation scheme consists of two thresholds known at the secondary user side. By comparing its SINR level to the first threshold (derived from capacity optimization step), the secondary user has the possibility to check whether it can be considered as a good candidate to start a communication or not. Then the SU checks the signaling channel broadcasted by the BTS and compares the broadcasted number of active users to the second threshold (derived from outage probability constraint). If this number is below the fixed threshold, the SU starts its transmission. After detecting the secondary user activity, the BTS sets its state as “active” in the broadcasted signaling channel and so on. As for the centralized mode, the approach based on outage probability prevents secondary systems from full drop of its capacity when the primary system starts its activity.

In real systems, the information about the outage failure can be carried out by a band manager that mediates between the primary and secondary users, or can be directly fed back from the primary user to the secondary transmitters through collaboration and exchange of the CSI between the primary and secondary users.

This distributed resource allocation schemes is also candidate for implementation in Sendora distributed ad hoc network scenario.

Reference

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